



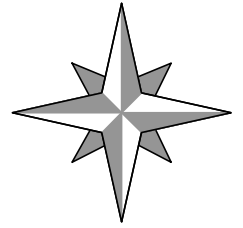
Carnegie Mellon
Software Engineering Institute

Reducing System Acquisition Risk with Software Architecture Analysis and Evaluation

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Topics

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Motivation for software architecture analysis

Architecture analysis methods

Integrating architecture analysis and evaluation into a system acquisition

Example of an integrated approach

RFP/contract language considerations

Summary

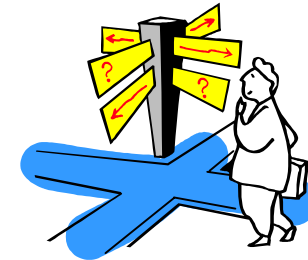
References



Objective

To provide guidance on integrating **software architecture analysis and evaluation** in DoD and Government system acquisitions.

This presentation contains both implicit and explicit guidance. We will use this **icon** to indicate when we are giving **explicit guidance**.



The guidance is based on **real experience** and a series of **technical notes and reports** that were developed by the Business and Acquisition Guidelines (BAG) group of the Product Line Systems Program at the SEI. (See References.)



Key Definition

The **software architecture** of a program or computing system is the structure or structures of the system, which comprise software elements, the externally visible properties* of those elements, and the relationships among them.

* assumptions other elements can make of a element, such as its provided services, performance characteristics, fault handling, shared resource usage, and so on

Reference:

Software Architecture in Practice, 2nd Edition;

Bass, L.; Clements, P.; & Kazman, R. Reading, MA: Addison-Wesley Publishing Co.,
Spring 2003.

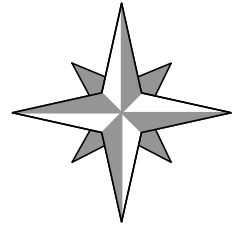


Terminology

Architecture analysis refers to analyzing a system's software architecture in accordance with a prescribed method.

Evaluation is used strictly in an acquisition context—i.e., in reference to performing an appraisal during source selection or contract performance.

Architecture analysis and evaluation means analyzing an architecture (and reporting the results) and evaluating the analysis results in strict accordance with the technical evaluation criteria of Section M of the RFP or the terms of the governing contract.



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Why Is Architecture So Important?

Architecture is a common high-level **communication vehicle** for system stakeholders that is amenable to analysis and synthesis.

Architecture embodies the **earliest set of design decisions** about a system. These decisions

- are the most profound
- are the hardest to get right
- ripple through the entire software development effort
- are most costly to fix downstream
- are critical to achieving mission/business goals

The earlier we reason about tradeoffs, the better. Architecture provides a powerful way to **predict system qualities**.



Software Versus System Acquisition

“We buy systems, not software.”

Promoting this message to DoD acquirers translates into “don’t worry about software.”

Reality:

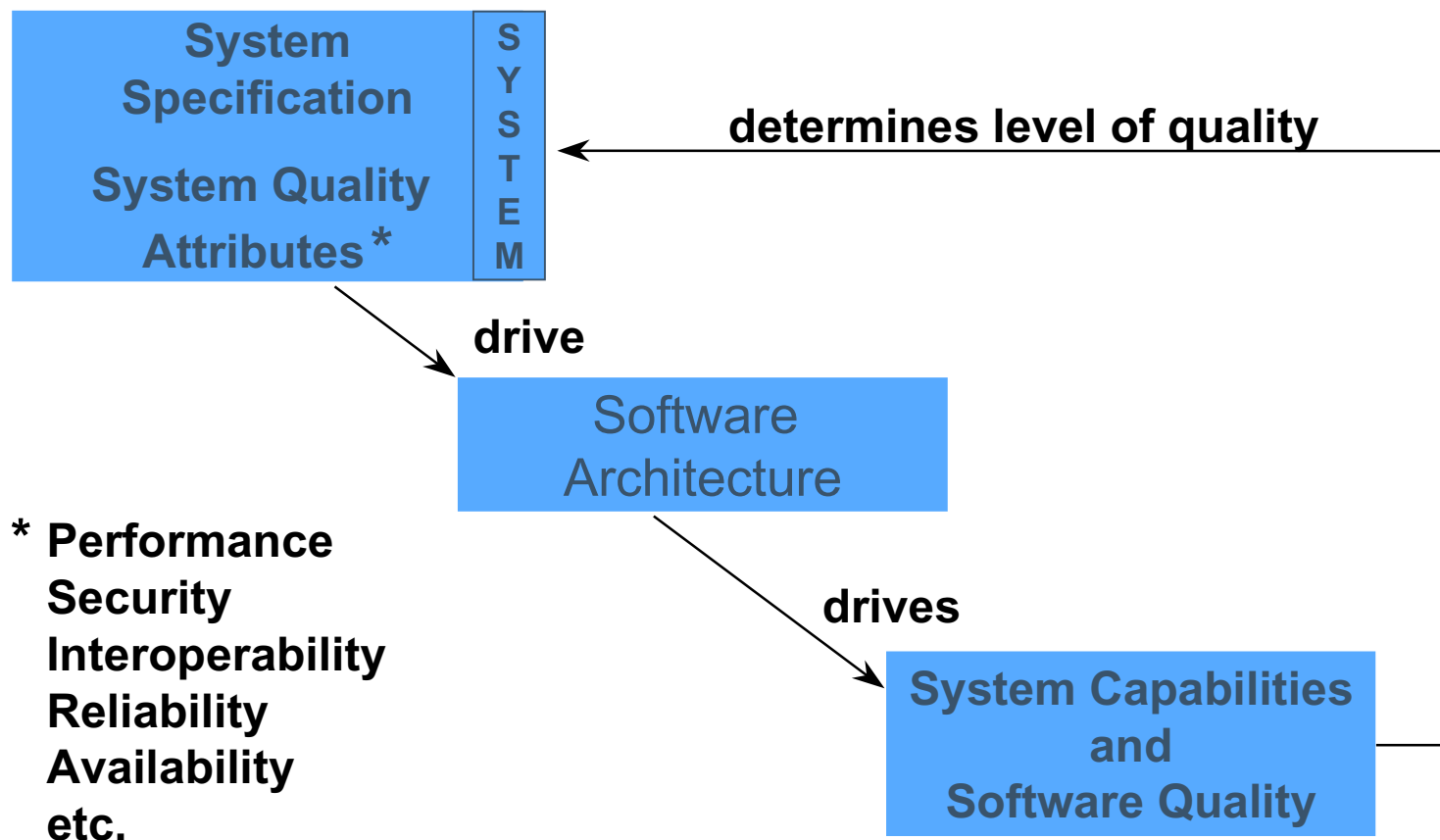
You should worry about software.

Software is critical to systems.

Software and software architectures drive both functionality and system quality.



Relationship of System Requirements to Software Architecture





Being Proactive Pays Off

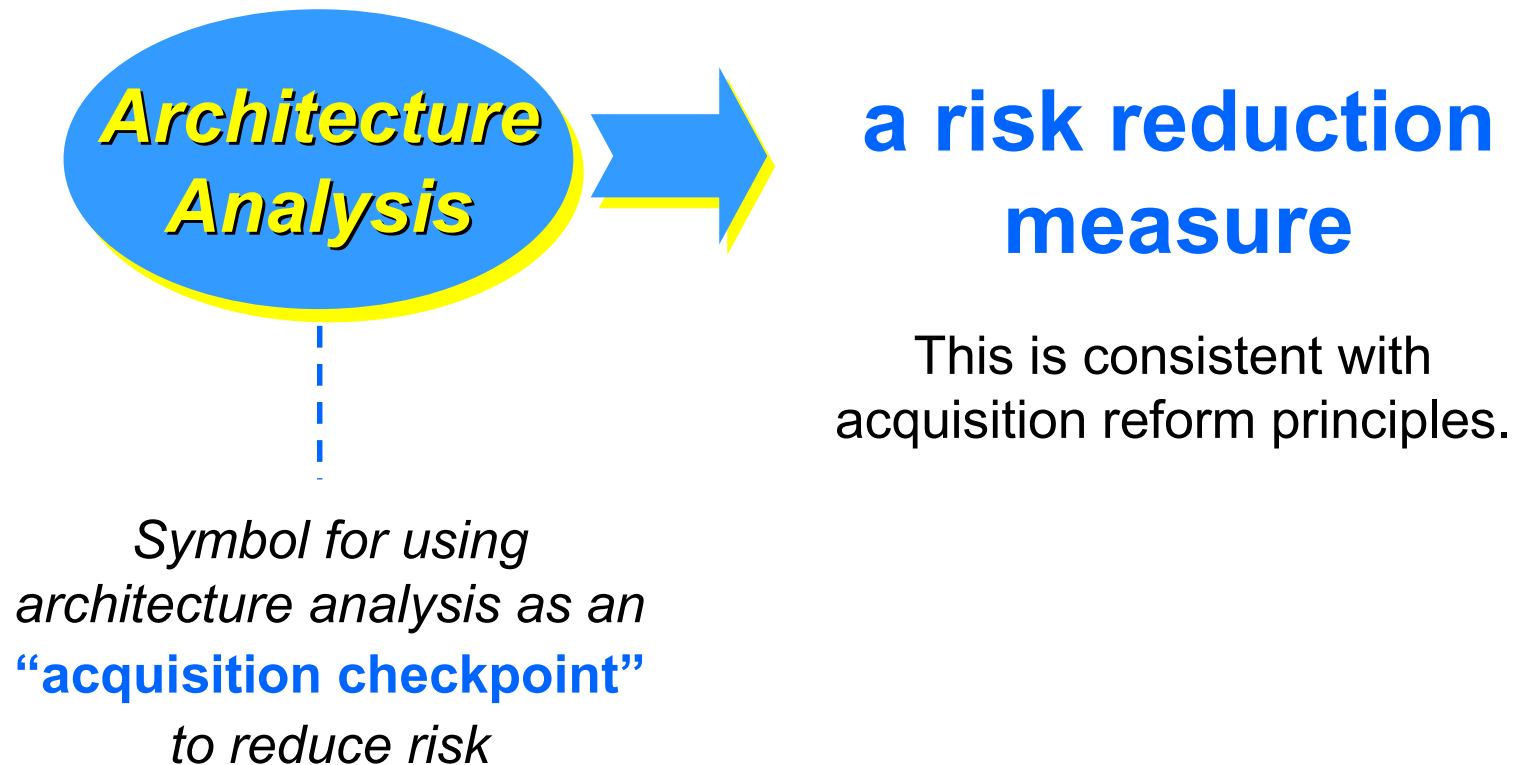
Architecture analysis and evaluation enables an acquisition program to

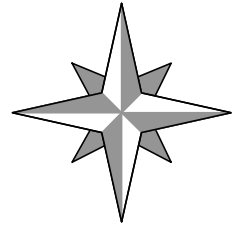
- obtain early visibility and technical insight into
 - system concept of operation
 - system and software design decisions and tradeoffs
 - ability to achieve desired system quality attributes
- achieve increased stakeholder communication across and within government and contractor organizations
- identify and reduce risk early on—for new and legacy systems

**The results
are improved
architectures**



Justification for Architecture Analysis and Evaluation in a System Acquisition





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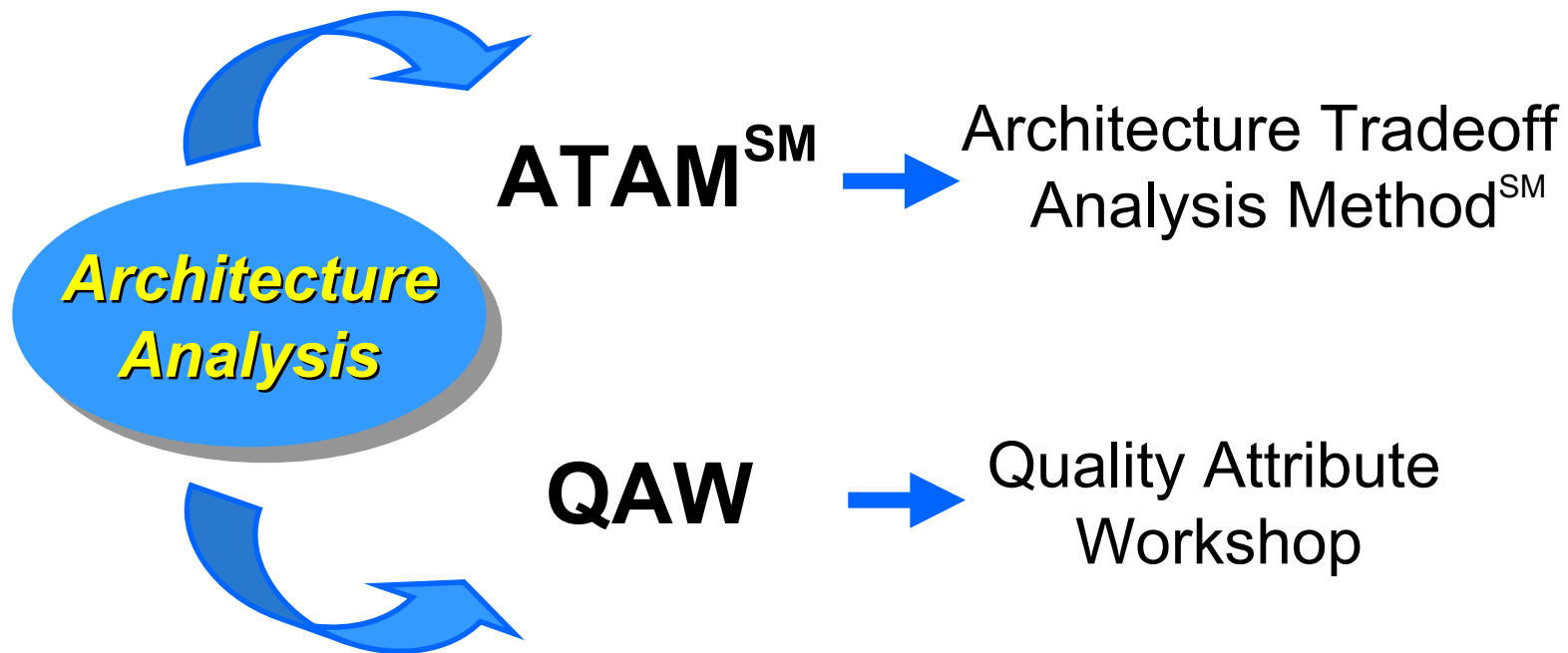
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SEI's Architecture Analysis Methods

The term “architecture analysis” encompasses both



Need to

- *choose an analysis method that fits your approach*
- *implement a compatible acquisition infrastructure*

SM Architecture Tradeoff Analysis Method and ATAM are service marks of Carnegie Mellon University.



The Analysis Methods

ATAM

- Purpose: to assess the consequences of architectural decisions in light of quality attribute requirements and business goals
 - uncover risks created by architectural decisions
 - surface design tradeoffs
- Requires identified business goals and a sufficiently documented software architecture

QAW

- Purpose: to help determine key quality attributes and system requirements *before* there is a software architecture to which the ATAM could be applied



Characteristics of ATAM and QAW

ATAM

- Uses extensive analysis of software attributes against quality drivers
- Involves broad range of stakeholders
- Requires close collaboration with architecture development team

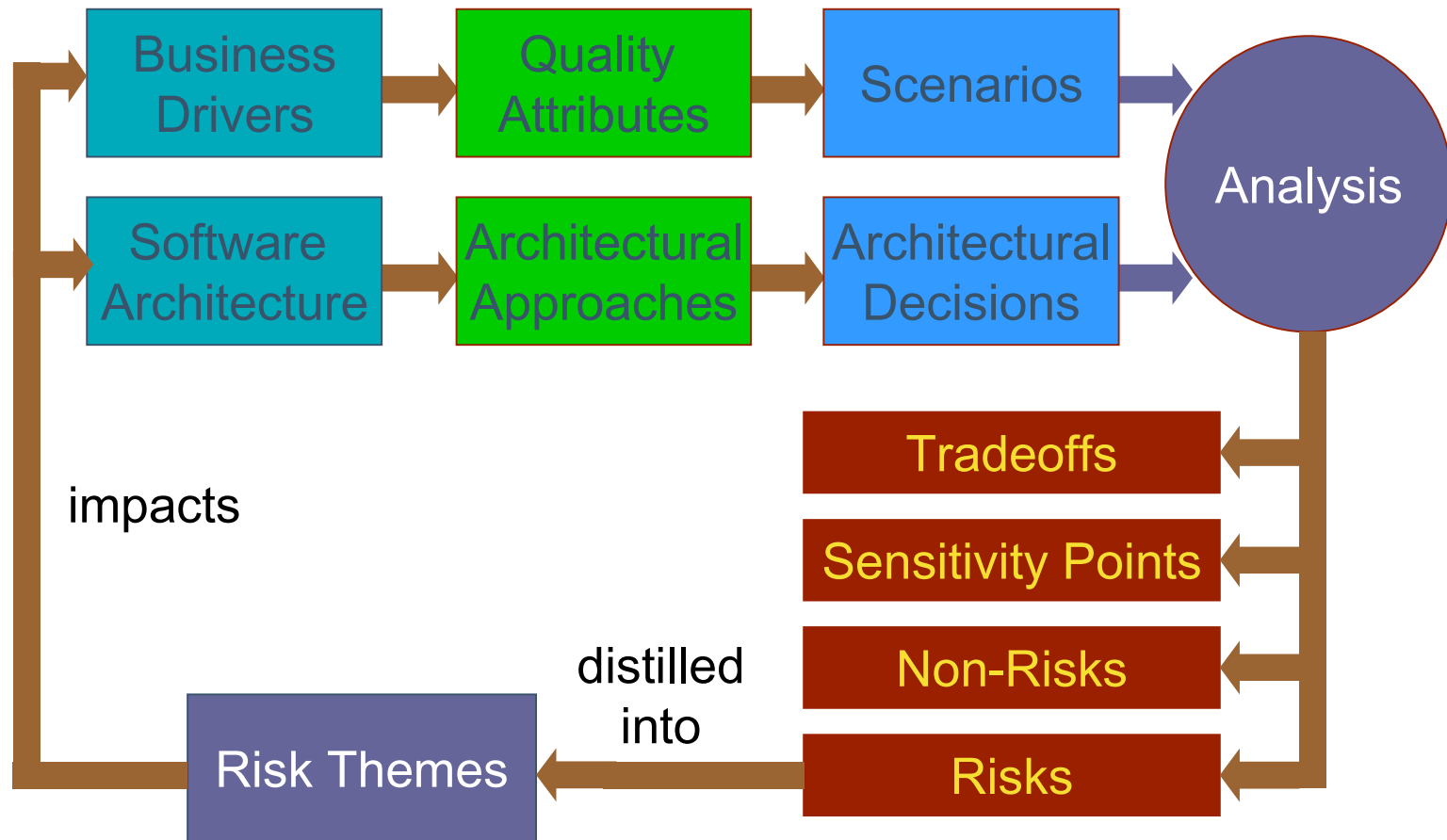
QAW

- Complementary offshoot of ATAM
- Intended for early stages of conceptual architecture development
- Can begin while the software architecture is still being crafted
 - Elements of a system and software architecture will suffice.
- Can be done offline by developer

**Both emphasize
communication
with stakeholders**



ATAM Overview





ATAM Benefits

Provides visibility into the consequences of architectural decisions in light of quality attribute requirements

- risks are explicitly identified
- architecture sensitivity points are determined
- tradeoffs are made more explicit

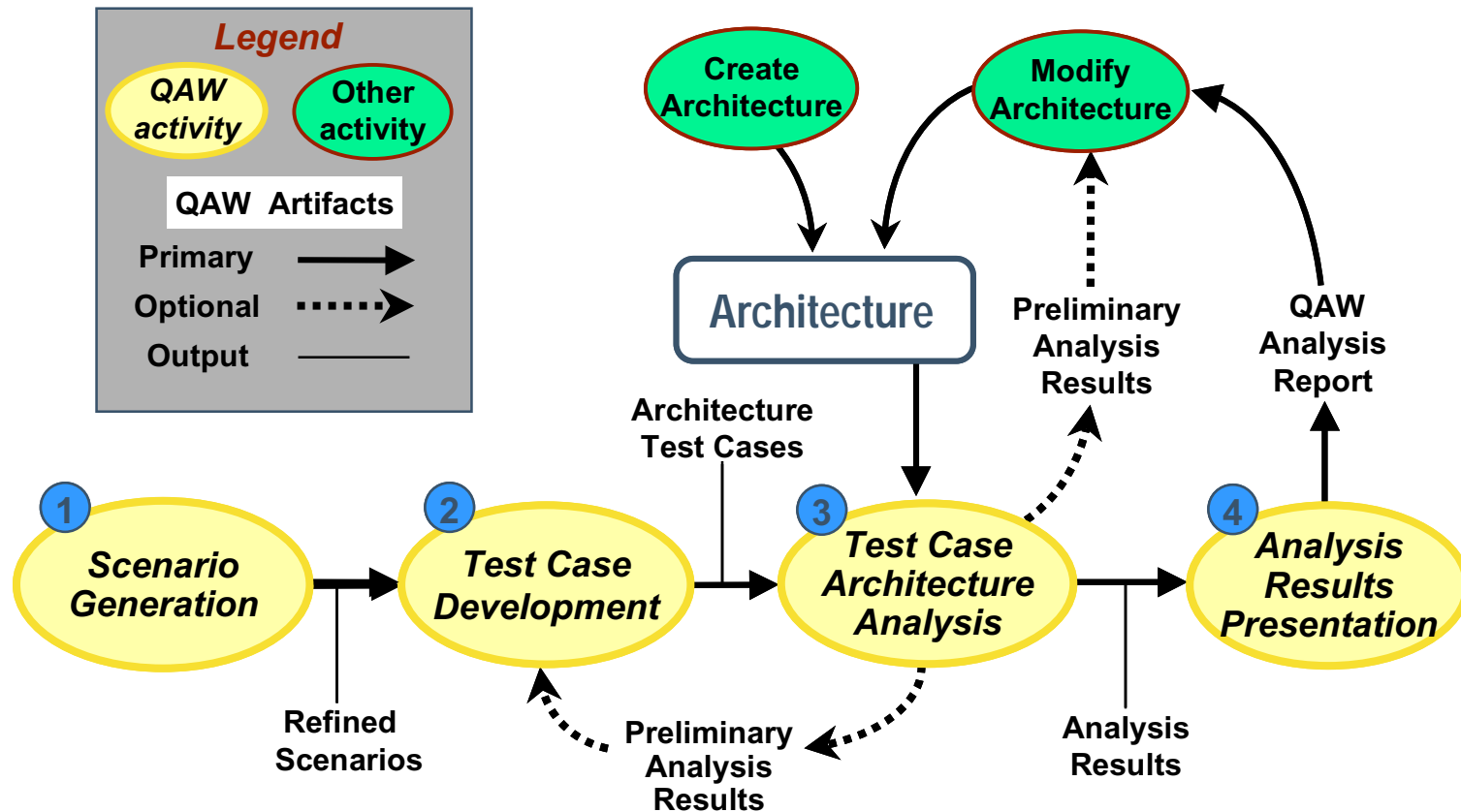
Increases communication among stakeholders

Provides documented basis for making architectural decisions

The results are [improved software architectures](#).

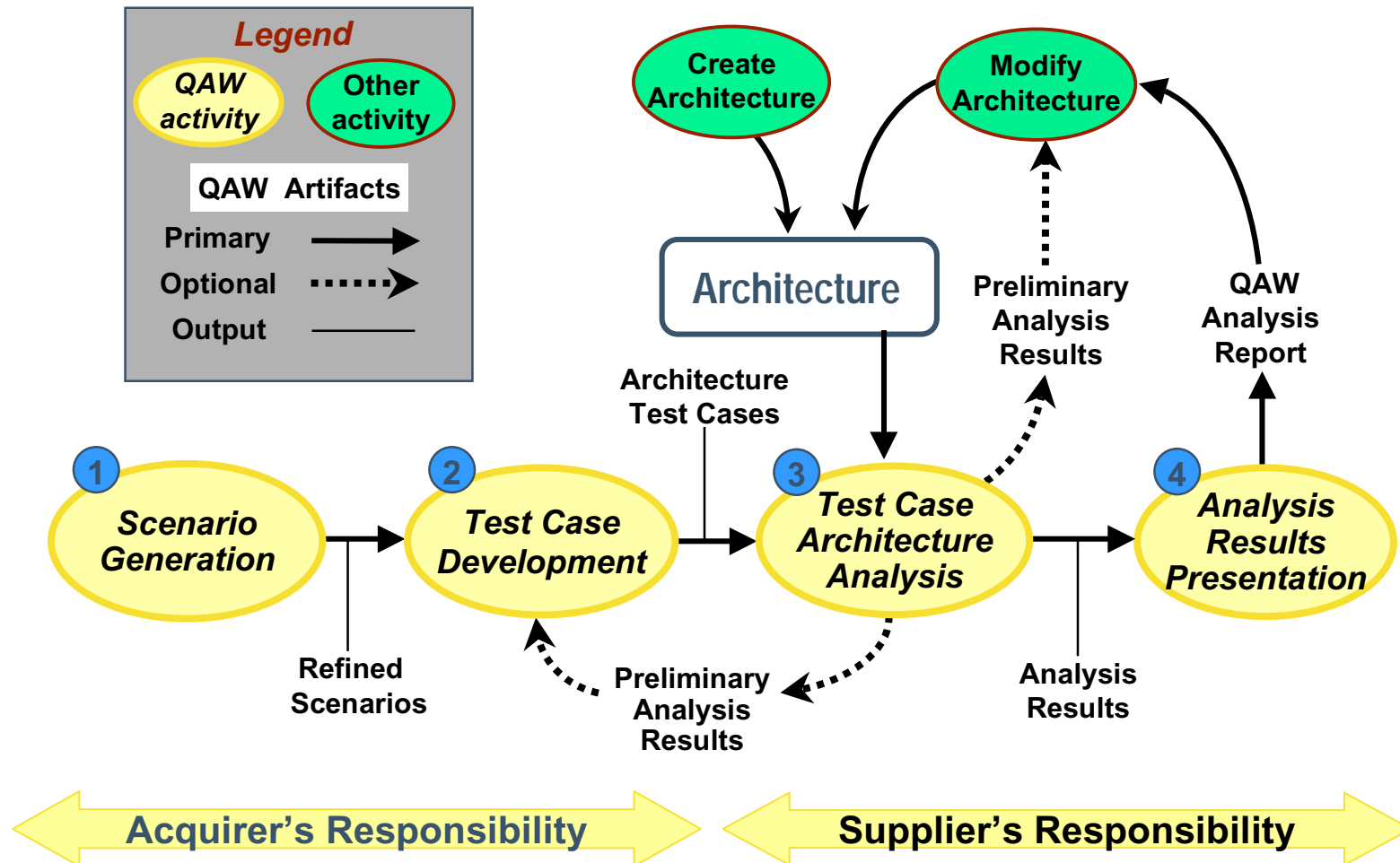


QAW Process





QAW Process – In DoD Environment





QAW Benefits

Clarifies business drivers and quality attribute requirements

Allows generation of scenarios and test cases before there is a software architecture

Results in improved architecture documentation

Allows risks to be identified early in the life cycle

Provides documented basis for architectural decisions

Increases communication among stakeholders

The results are [improved conceptual architectures](#).



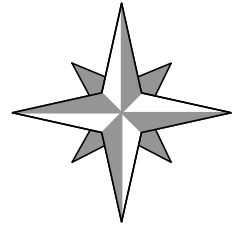
Conditions for using ATAM or QAW

ATAM

- Stakeholders want to evaluate the software architecture.
- Business drivers and system quality attributes are well understood.
- Software architecture is suitably documented.
- Architecture development team is available for engagement.

QAW

- An architecture analysis is desirable to reduce risk.
- Business drivers and system quality attributes need refinement.
- There is only a conceptual architecture and limited architectural documentation.
- A very flexible analysis method is needed to allow for early intervention.



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Applying Architecture Analysis and Evaluation in a System Acquisition

In competitive acquisitions, architecture analysis and evaluation can be used to help manage the [solicitation](#) process, including source selections.

After contract award, architecture analysis can be used to help manage the [contract performance](#) process, including contractor performance and product evaluations.

How to use architecture analysis and evaluation most effectively depends on [your objectives](#) and [system acquisition strategy](#).



Architecture Analysis and Evaluation in Solicitation

Architecture analysis and evaluation can be used as a **discriminator** in the **source selection** process. Options include evaluating each offeror's

- related experience in architecture development and analysis
- ability to adequately plan an architecture analysis using a prescribed method
- actual progress against an approved analysis plan
- architecture analysis results
- demonstrated ability to take suitable remedial action and mitigate discovered risks



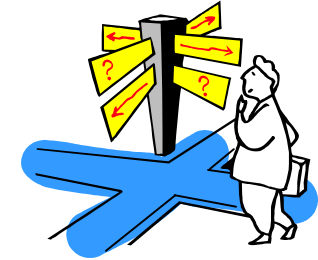
Architecture Analysis and Evaluation in Contract Performance

During **system development**, architecture analysis can be used to

- select an architecture among several candidate architectures
- assist in decision whether to upgrade or rebuild legacy system
- assist in architecture refinement once an architecture has been chosen
 - during progressive stages of software development
 - during evaluation of new system builds

During **system sustainment**, architecture analysis can be used to support system upgrades and reengineering.

During **system development and sustainment**, architecture analysis and evaluation can play a role in incentive awards to the degree specified in the contract.



Guidance: Basic Principles

Remember that

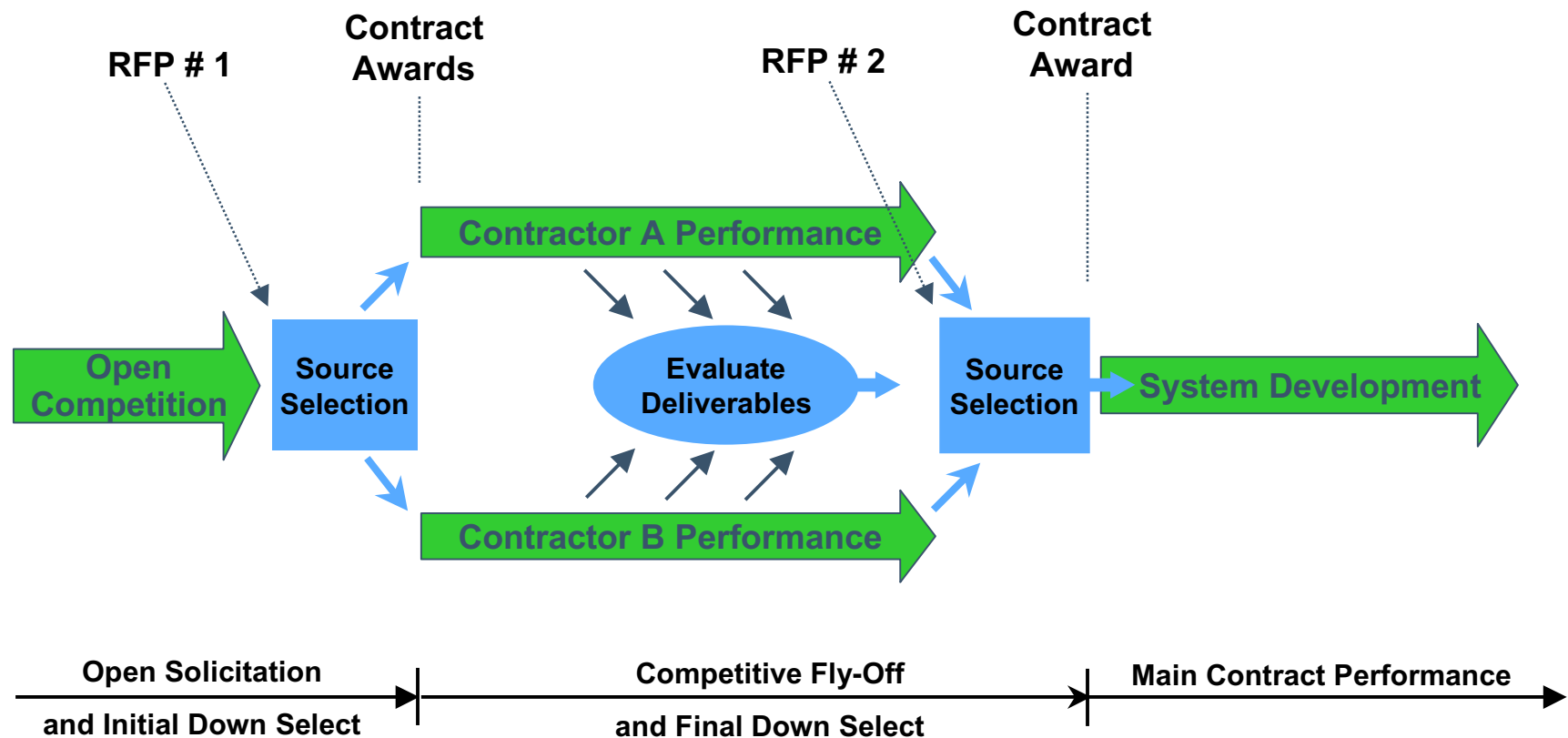
- One size doesn't fit all.
 - The approach for integrating **architecture analysis and evaluation** in a system acquisition has to be adapted to the situation.
- Success will depend on carefully planning a coherent approach and integrating it with the system acquisition strategy.
- **Analysis aspects** must faithfully adhere to the specified architecture analysis method.
- **Evaluation aspects** must comply with the FAR* and be specified up front in the RFP and contractual requirements.

**Be disciplined.
Tailor, plan,
and coordinate
the effort.**

** Federal Acquisition Regulations*



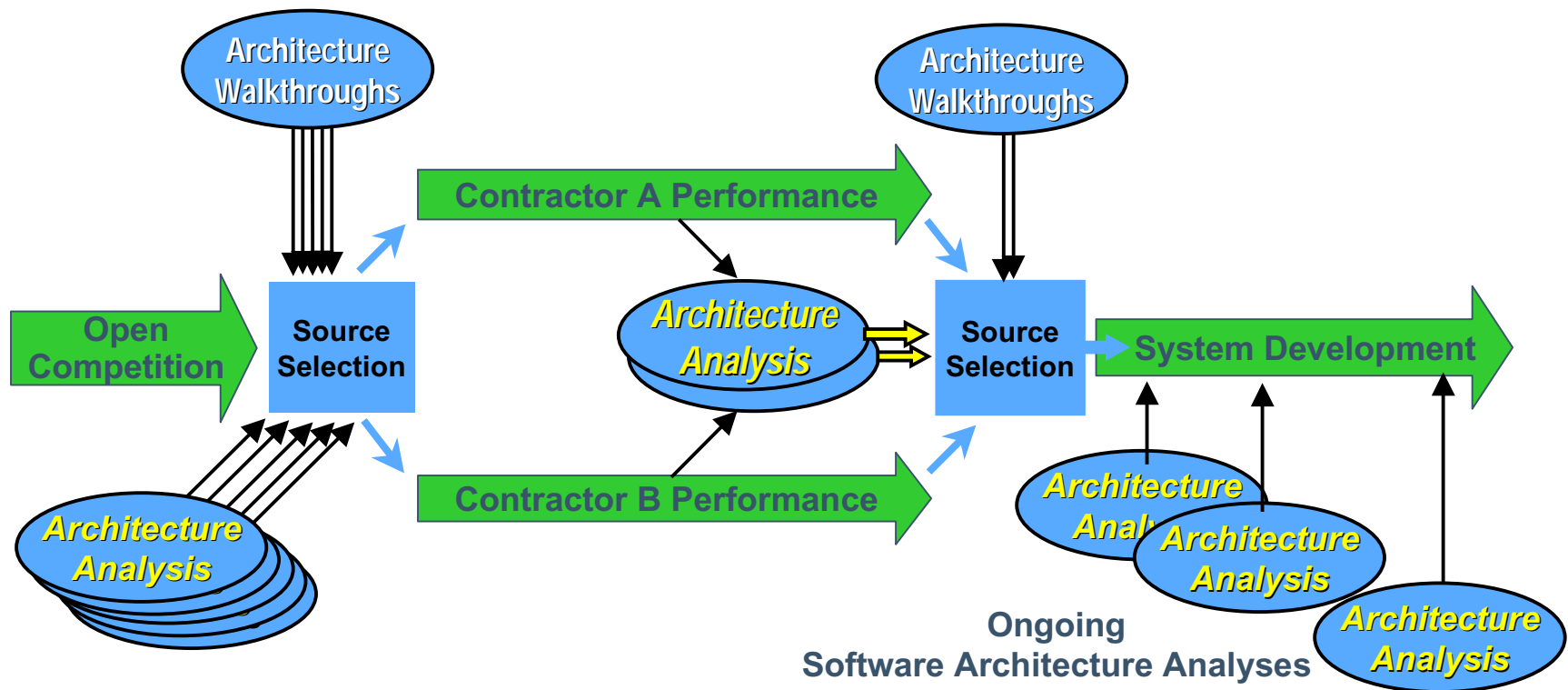
Example System Acquisition Strategy





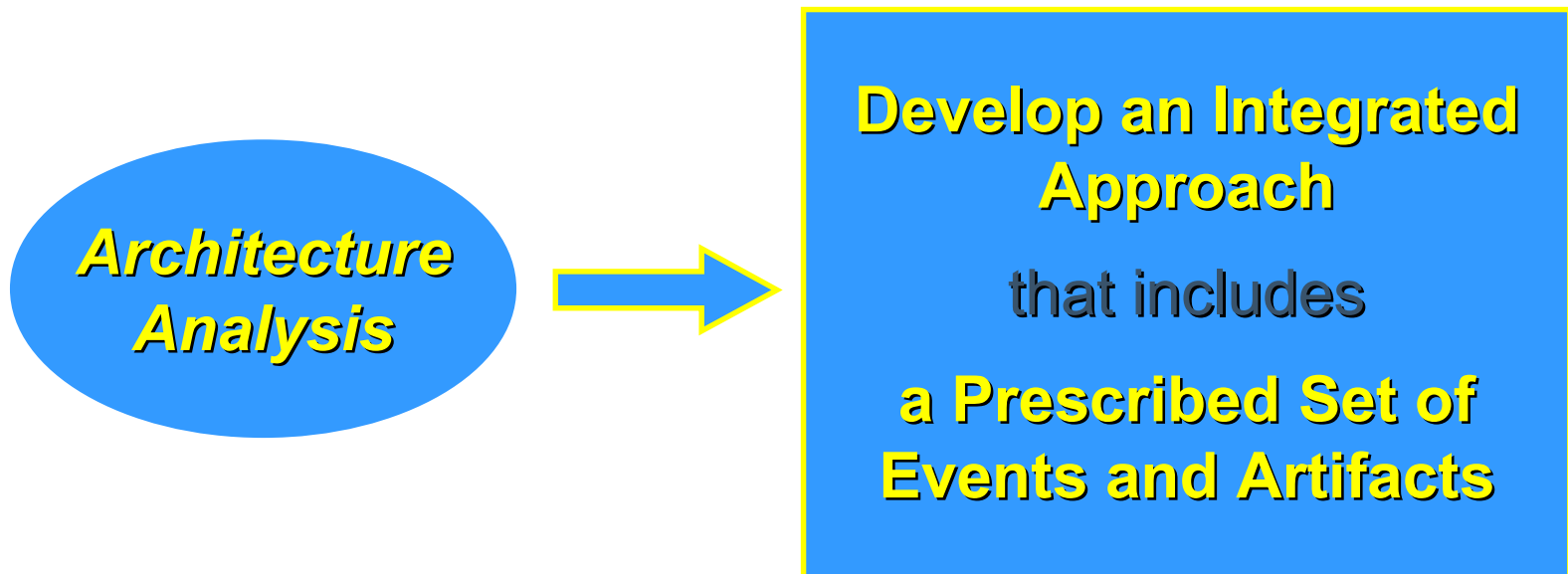
Potential Application of Architecture Analysis and Evaluation

Part of Oral
Technical Presentations





How Do You Incorporate Architecture Analysis and Evaluation in an Acquisition?



The purpose of these events and artifacts is to create a suitable acquisition infrastructure.



Guidance: Getting Started



To integrate architecture analysis and evaluation you will need to

**Understand
the acquisition
context and
supporting
technologies**

- understand the policies and constraints that govern the acquisition
- understand the system acquisition strategy and proposed technical evaluation criteria for the RFP/contract
- have a good working knowledge of the architecture analysis method to be applied
- understand how the system's technical requirements apply to the architecture analysis and evaluation
- strongly consider adopting a competitive fly-off strategy to reduce risk by allowing more detailed analysis (suppliers) and evaluation (acquirers)



Developing an Integrated Approach ¹

- Establish your **objectives** for incorporating architecture analysis and evaluation.
- Review the proposed **acquisition strategy**.
- Conduct a **brainstorming** session **with stakeholders** to explore how architecture analysis and evaluation can best be applied in source selection and contract performance.
- Select the most beneficial **course of action** that is compatible with the selected architecture analysis method.
- Identify what **events** must take place and what **artifacts** must be produced in each phase of the acquisition.



Developing an Integrated Approach ²

- Define a compatible set of **roles and responsibilities** for both the acquirer and supplier.
- Identify the **specific tasks** that the acquirer and supplier must perform in each phase of the acquisition and the artifacts that they must develop and deliver.
- Have stakeholders **review** and critique the proposed approach.
- Adjust the approach or acquisition strategy as necessary and obtain the approval of the **contracting officer**.
- Develop corresponding **RFP/contract** language to implement steps 4 through 9 in an effective manner.



Acquirer's Key Events and Artifacts

In planning the approach, give due consideration to

- specifying the **business/mission drivers**
- specifying the system **quality attributes** and **architecture test cases and architecture documentation**
- conducting a **tutorial** on the architecture analysis method for prospective offerors before issuing the RFP
- holding a **kickoff meeting** after contract award to describe
 - government expectations for the supplier's architecture analysis
 - rules of engagement for conducting the analysis and evaluation
- providing **formal feedback** on the analysis results
- having an **equitable basis for evaluating** the final outcome



Supplier's Key Events and Artifacts

In planning the approach, give due consideration to

- requiring suppliers to prepare a **preliminary architecture analysis plan** to demonstrate their understanding of the analysis method
- requiring suppliers to conduct a **dry run architecture analysis** to assess their level of preparedness
- requiring the active **participation of key stakeholders**, including the supplier's software architect
- incorporating an equitable means for suppliers to **deliver and present** their analysis results **and respond** to official feedback from the acquirer



Software Architecture Guidance

**DoD typically mandates use of
the C4ISR Framework.**

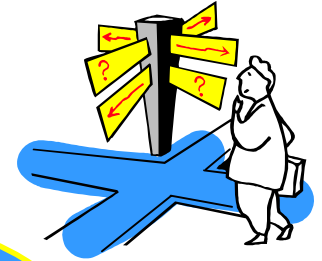
This often translates to “C4ISR is sufficient to address all architectural concerns.”

Reality:

The C4ISR Framework provides important context but is not a software architecture.



Guidance: In Developing Your Specific Approach



**Avoid
common
pitfalls**

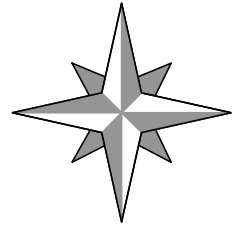
Accommodate all aspects of the architecture analysis method in the most practical, straightforward manner.

Ensure that the RFP development team is included in all the acquisition technical planning and decision-making activities.

Include the contracting officer in the planning process.

Ensure that companies contributing to RFP/contract preparation will exclude themselves from bidding to avoid a potential protest.

If adopting a competitive fly-off approach, use a Call for Improvement (CFI) instead of issuing another RFP.



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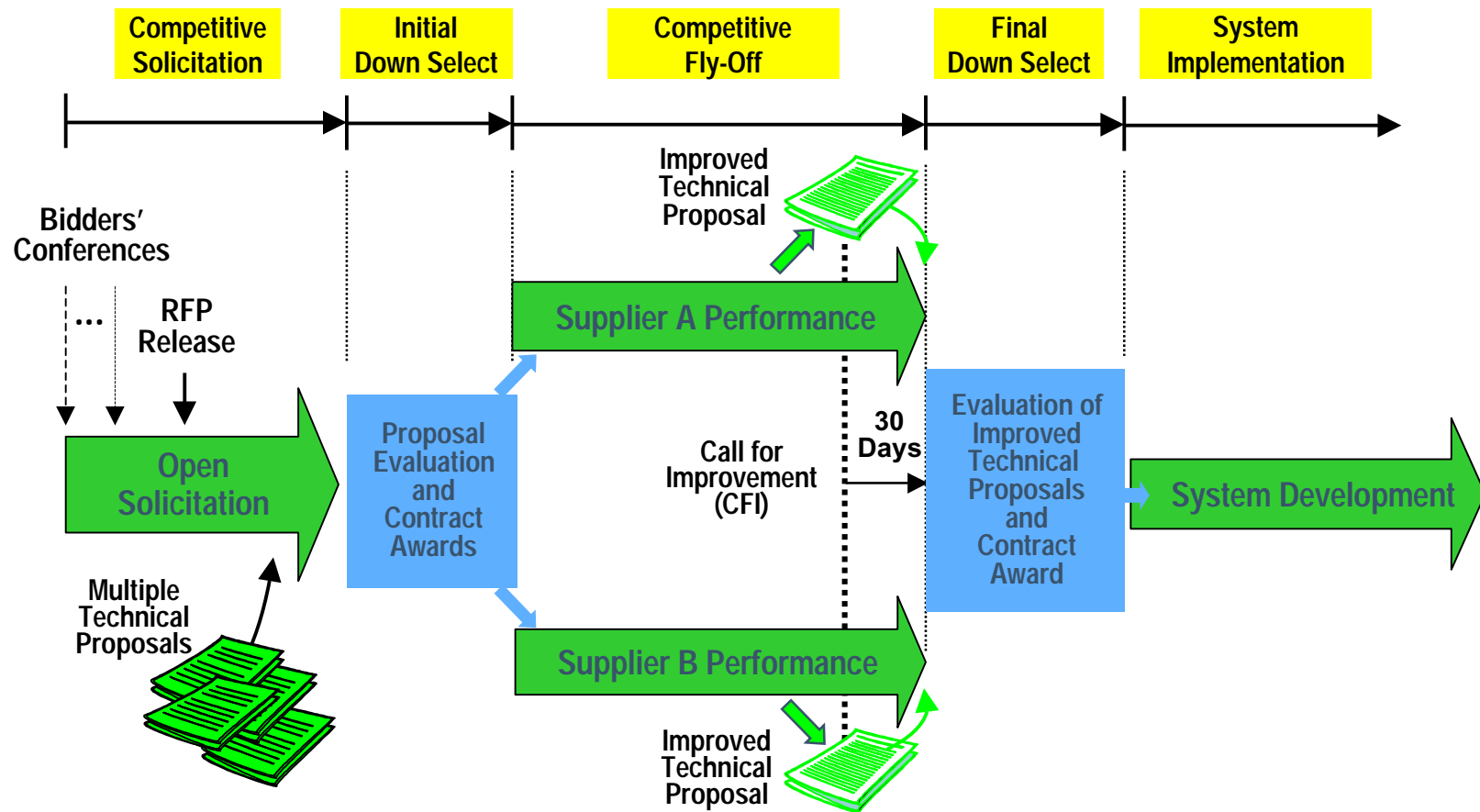
→ **Example of an integrated approach**

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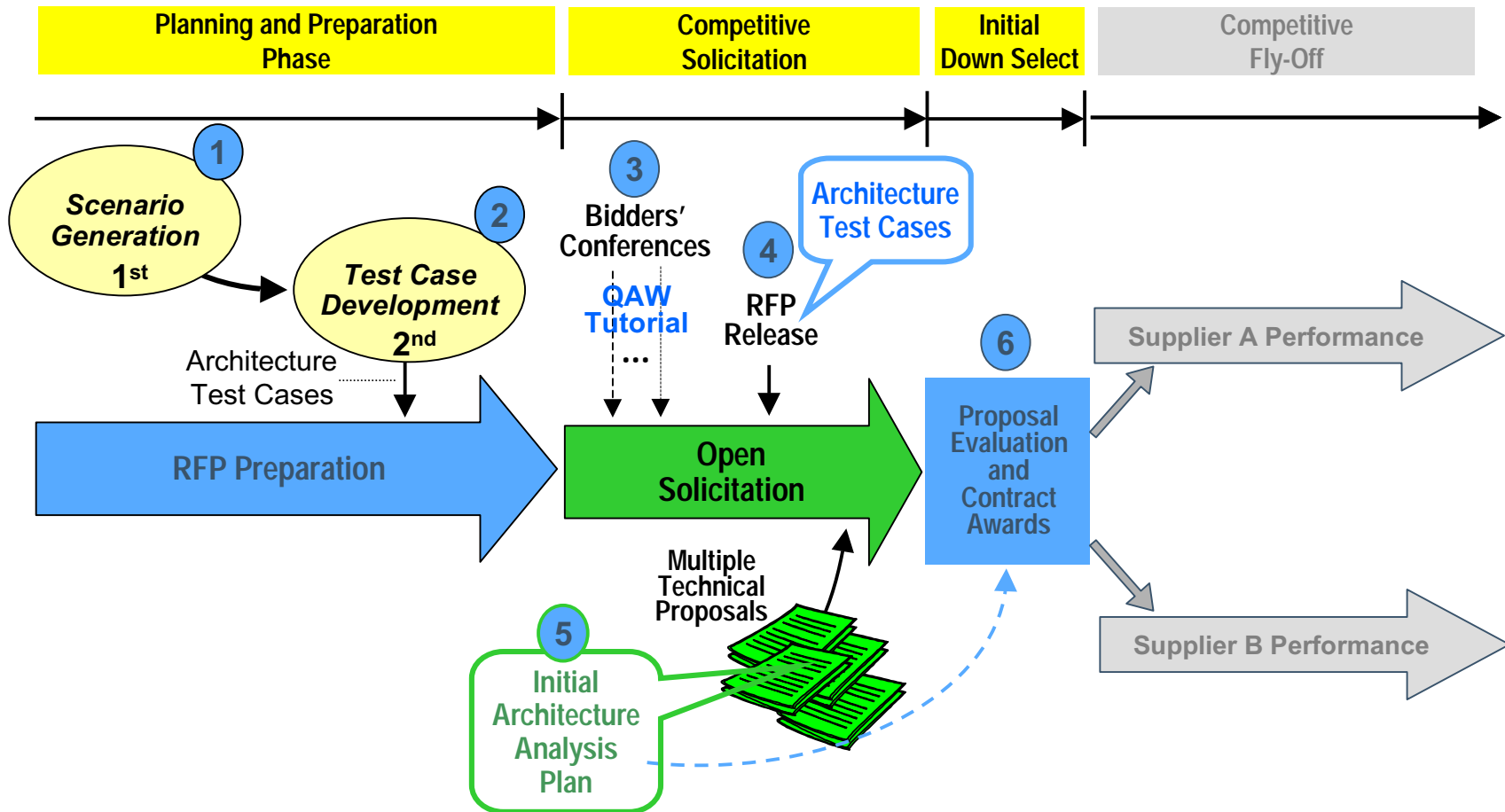


Example System Acquisition Strategy



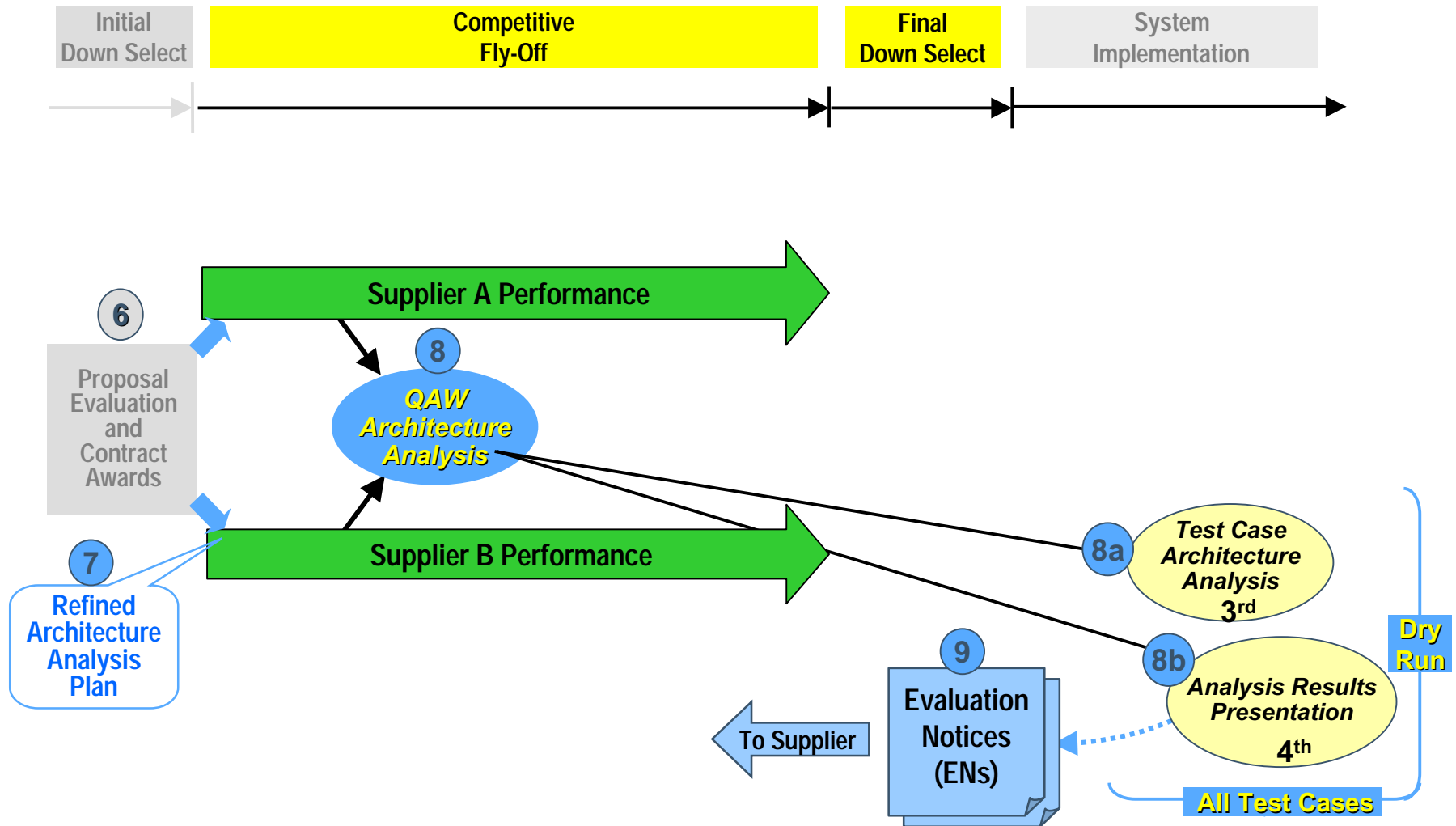


Integrating a QAW (Part 1)



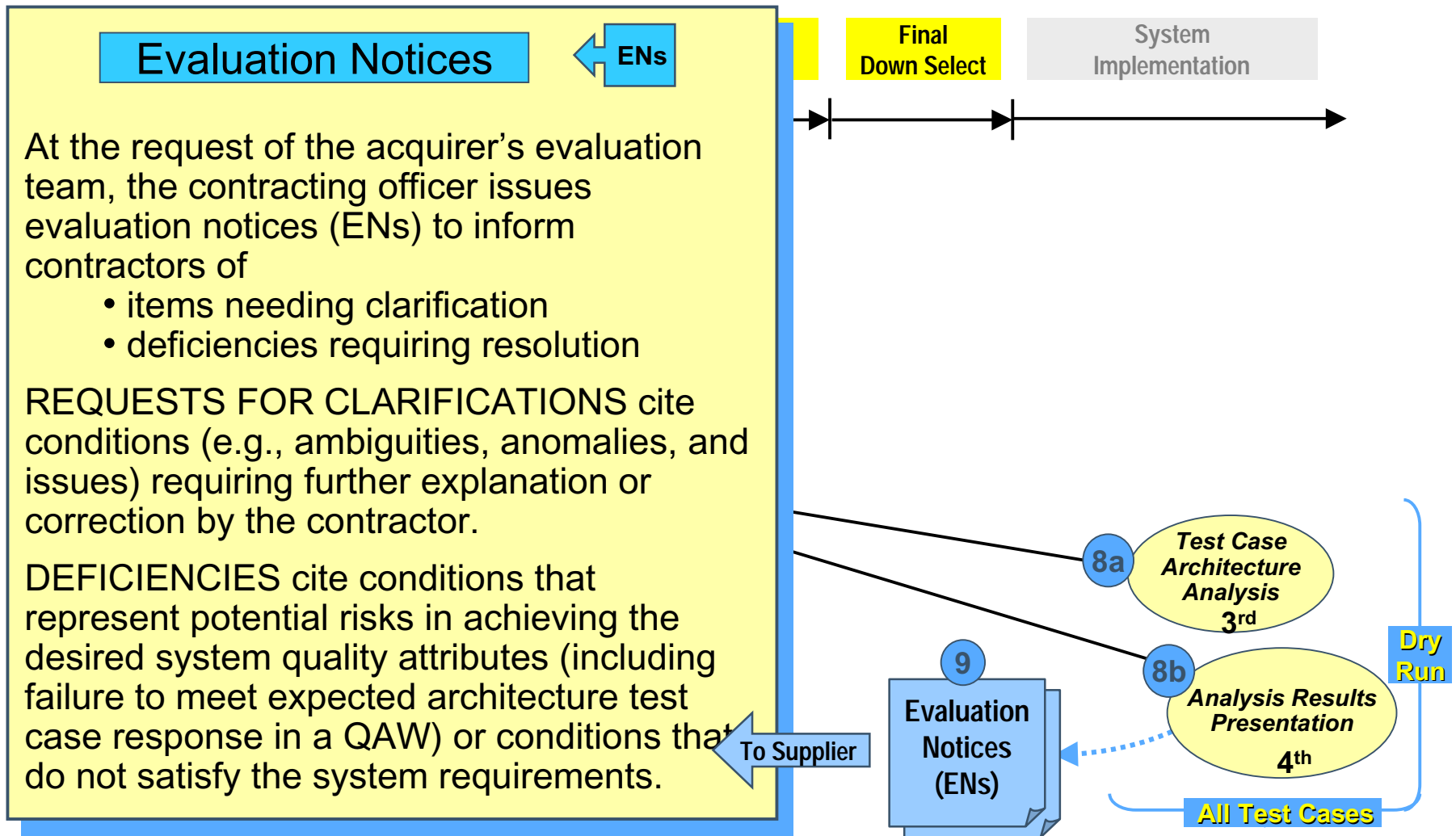


Integrating a QAW (Part 2)



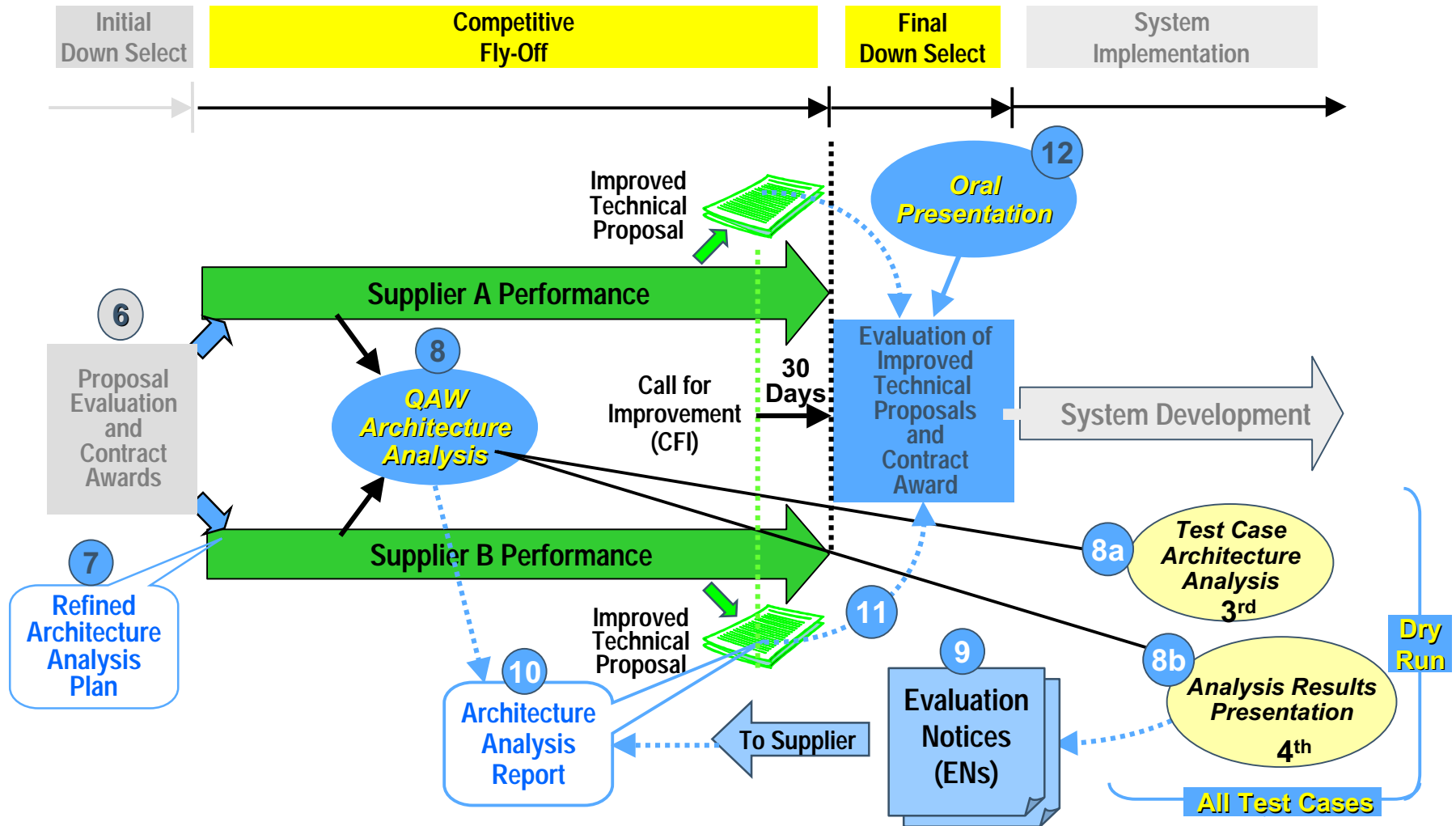


Integrating a QAW (Part 2 with EN)



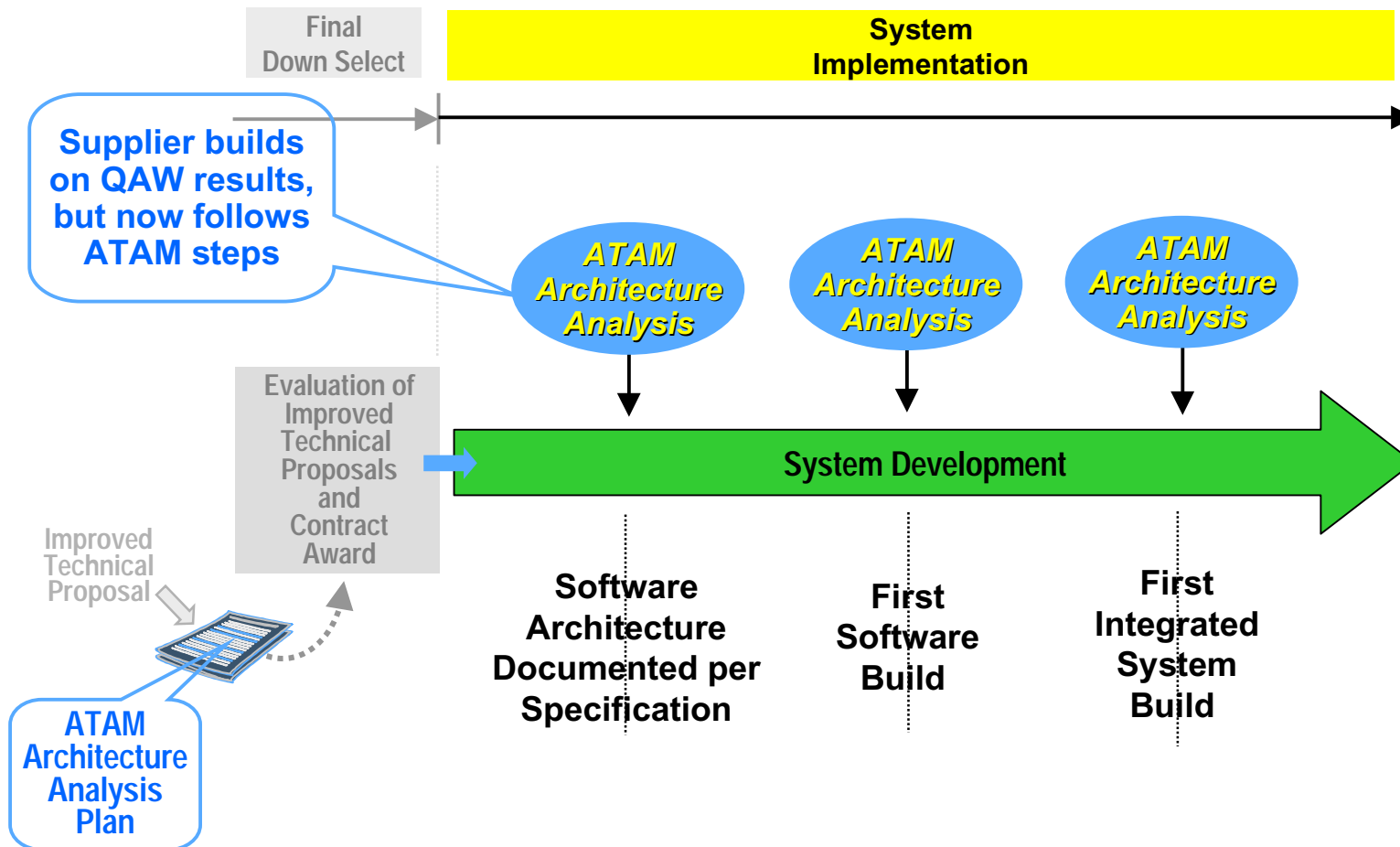


Integrating a QAW (Part 2 Continued)





Integrating ATAM (Part 3)





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Implementing the Architecture Analysis and Evaluation Approach

What happens during solicitation and contract performance critically depends on what is included in the **RFP** and the **resulting contract**.

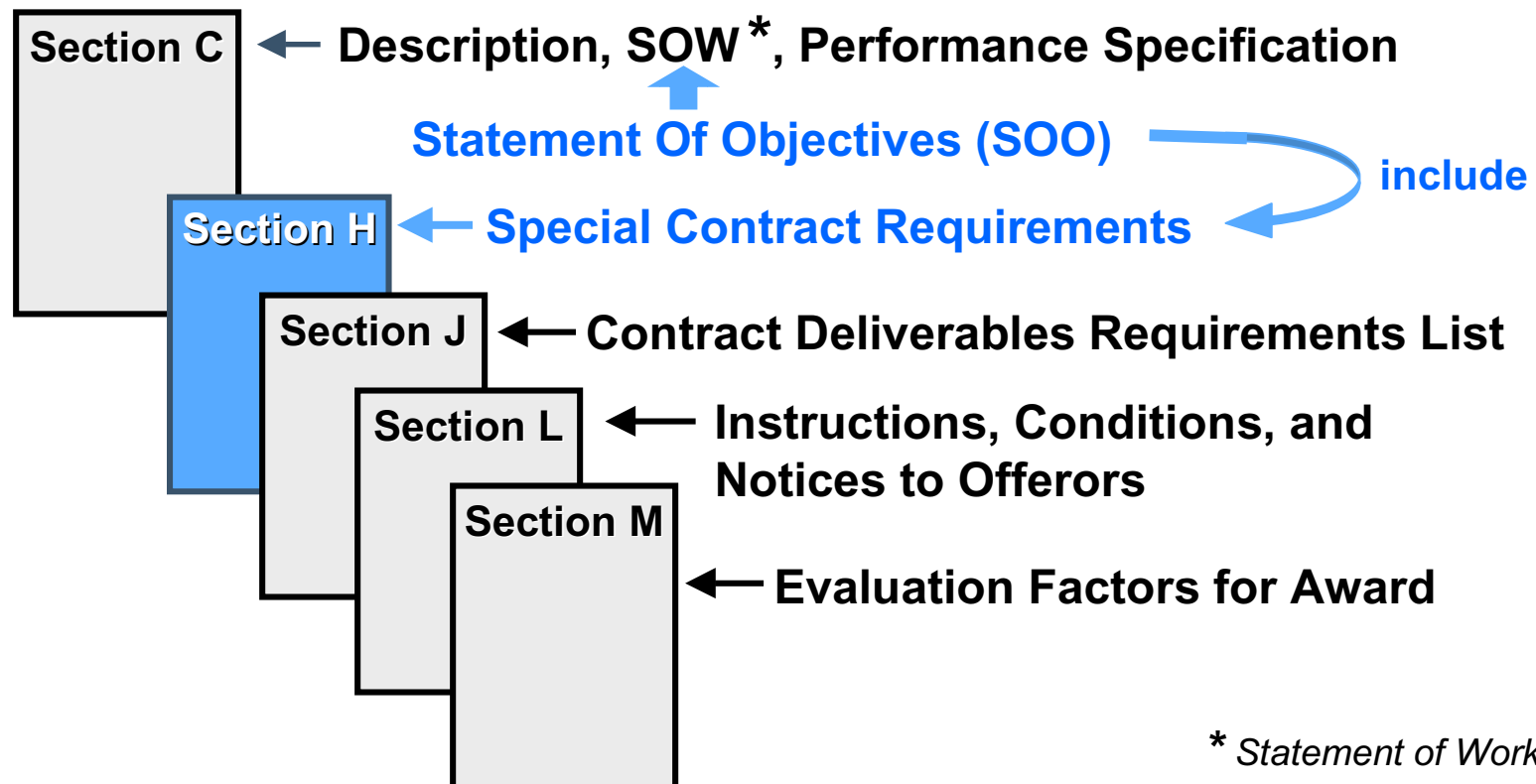
Appropriate RFP/contract language must be developed to make architecture analysis and evaluation an integral part of evaluating proposals as well as evaluating system aspects.

Only the RFP and contract language can give the government the **means to manage** the suitability of the software architecture.



RFP/Contract Sections

Incorporating architecture analysis requires developing appropriate language for the following sections:





Performance Specification*

Contains two sections of interest:

- Section 1 covers the **technical requirements** for the acquisition.
- Section 2 describes the **mechanisms** for confirming that requirements have been met.

Section 1 specifies **system quality requirements** from which software architecture requirements (runtime and non-runtime) are derived.

They must be stated in terms of

- definition of **system quality attributes**
- specification of **acceptable values**
- definition of **scenarios and test cases**
- specification of **other requirements** (e.g., C4ISR)

Section 2 includes a description of the **architecture analysis method**.

** System Specification or Technical Requirements Document*



Section H: Special Contract Requirements

Section H will specify

- the architecture analysis requirements
- the artifacts that are to be developed
- rules of engagement (ROE)

Section H will describe

- when the architecture analysis should be performed
- how the analysis should be conducted
- contractor and government roles and responsibilities
- how the results will be used



Typical Rules of Engagement (ROE)

- Offerors will submit architecture analysis **plan** with proposal based on government-prescribed architecture analysis method.
- Contracting officer will notify selected suppliers of any **deficiencies** in their analysis plan.
- Supplier will conduct architecture **analysis** and present **results** in accordance with its approved plan.
- Contracting officer will issue **evaluation notices** (ENs) to suppliers following presentation of analysis results.
- Suppliers are required to **respond** to all ENs.
- Contract takes precedence over the architecture analysis plan.
- Analysis **results** are **evaluated** in accordance with contract or technical evaluation criteria of Section M of RFP.



Software Architecture Documentation

There are no DoD Data Item Descriptions (DIDs) specific to architecture.

However, some DoD organizations have tailored the following DIDs from DoD-2167A that contain architecture information to meet their acquisition needs:

- System/Subsystem Design Document (SSDD)
- Software Design Document (SDD)

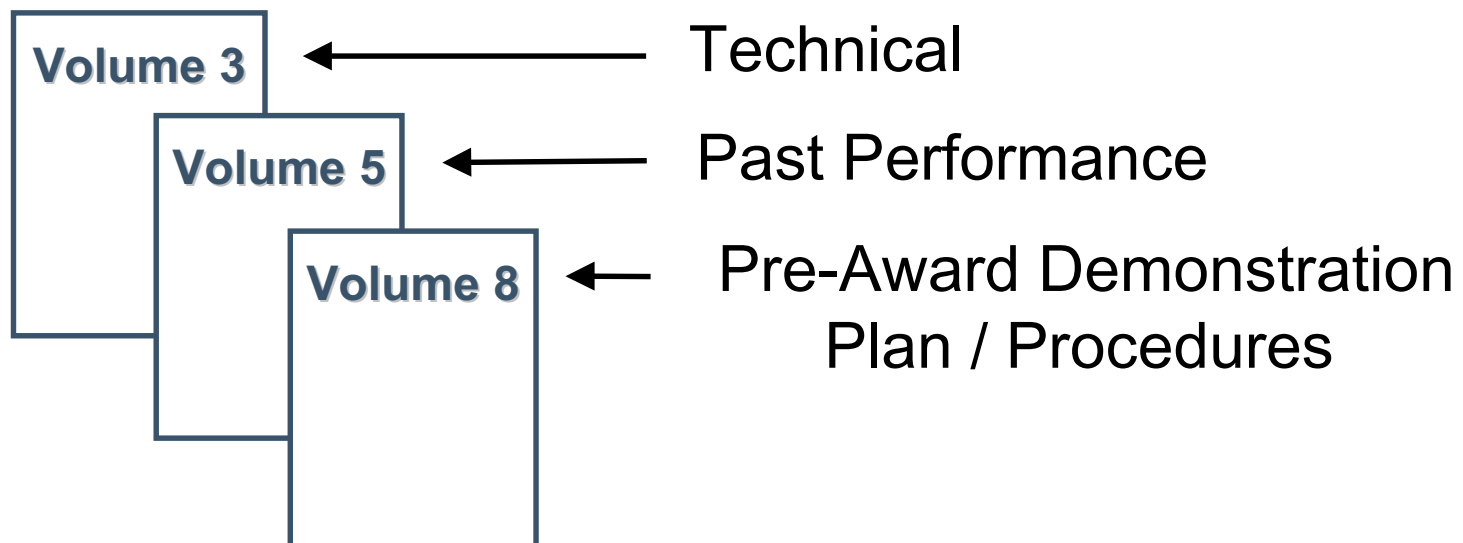
Under acquisition reform, many contractors will describe the specific artifacts and documentation they will prepare per their own internal processes.



RFP Section L

Section L describes what offerors should address in their proposal; that is, which requirements in the RFP need a response.

Offerors prepare multiple volumes.





Specific Section L Volumes

In the [Technical volume](#), you ask offerors to describe their approach for implementing and analyzing architecture requirements.

In the [Past Performance volume](#), you ask offerors to describe previous work on software architecture development and architecture evaluation.

In the [Pre-Award Demonstration volume](#), you give offerors requirements for demonstrating the capability of their software architecture.



RFP Section M: Evaluation Criteria

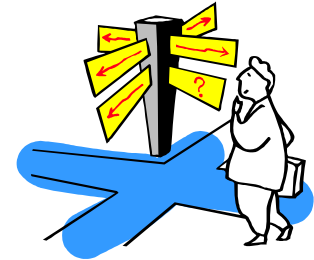
Section M tells offerors how their proposals will be evaluated.

It should specify

- the ranking of evaluation factors
- how architecture analysis is made part of the specific evaluation factors
- the evaluation criteria for judging the proposal submission and how results of the architecture analysis will be included in the technical evaluation



Guidance: Some Precautions

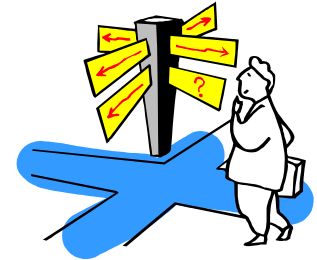


To avoid potential problems

- Understand the policies and criteria that the acquisition review board will use as part of the RFP review and approval process.
- Make sure the architecture analysis and evaluation approach has the “buy in” of the contracting officer.
- Firm up the acquisition strategy and technical evaluation criteria early in the acquisition planning phase.
- Resist management pressures to arbitrarily compress the acquisition schedule, including RFP preparation.
- Include personnel with domain and architecture expertise on the RFP development team.

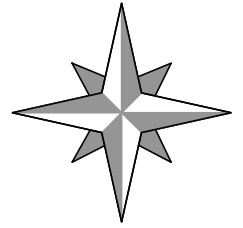


Guidance: RFP Preparation



It takes time to carefully draft the right wording for architecture analysis and evaluation and integrate it into an RFP in a manner that is compatible with the acquisition strategy and addresses all the key issues.

If you rush your preparation of the RFP you will likely increase downstream risk and not reap all the benefits of an architecture-centric acquisition approach.



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Summary ¹

Architecture Analysis

Our acquisition example illustrates the use of software architecture analysis and evaluation in source selection and contract performance.

A prescribed set of events and artifacts can be used to integrate architecture analysis and evaluation in a system acquisition.

This approach works with any system and software development methodology.

RFP and contract language alone can give the acquirer the capability to manage the system quality of the architecture.



Summary 2

Reducing Acquisition Risk

Architecture analysis and evaluation provide an effective means for

- mitigating risks in a system acquisition
- evaluating the achievement of system quality attributes that are important to the program
- changing customary program assumptions about software oversight that underlie system acquisitions

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Clements, P.; Bachmann, F.; Bass, L.; Garlan, D.; Ivers, J.; Little, R.; Nord, R.; & Stafford, J. Reading, MA: Addison Wesley Publishing, Co., 2002.

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Barbacci, M.; Ellison, R.; Lattanze, A.; Stafford, J.; Weinstock, C.; & Wood, W. Pittsburgh, PA: Software Engineering Institute, Carnegie Mellon University, 2002.

www.sei.cmu.edu/publications/documents/02.reports/02tr019.html



Technical Notes on Architecture Analysis in Acquisition 1

CMU/SEI-2002-TN-010

Use of the Architecture Tradeoff Analysis MethodSM (ATAMSM) in Source Selection of Software-Intensive Systems

CMU/SEI-2002-TN-013

Use of Quality Attribute Workshop (QAW) in Source Selection for a DoD System Acquisition: A Case Study

CMU/SEI-2001-TN-010

Use of the Architecture Tradeoff Analysis MethodSM (ATAMSM) in the Acquisition of Software-Intensive Systems



Technical Notes on Architecture Analysis in Acquisition 2

CMU/SEI-2000-TN-010

Using Quality Attribute Workshops to Evaluate Architectural Design Approaches in a Major System Acquisition: A Case Study

CMU/SEI-99-TN-012

Software Architecture Evaluation with ATAMSM in the DoD System Acquisition Context



Related Technical Notes and Reports

CMU/SEI-2001-TN-022

Using the Architecture Tradeoff Analysis MethodSM to Evaluate a War Game Simulation System: A Case Study

CMU/SEI-2000-TN-007

Using the Architecture Tradeoff Analysis MethodSM to Evaluate a Reference Architecture: A Case Study

CMU/SEI-99-TR-014

Architecture Tradeoff Analyses of C4ISR Products



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